Open + Reproducible Research Webinar for USGS

Practical steps for increasing the openness and reproducibility of research

April Clyburne-Sherin

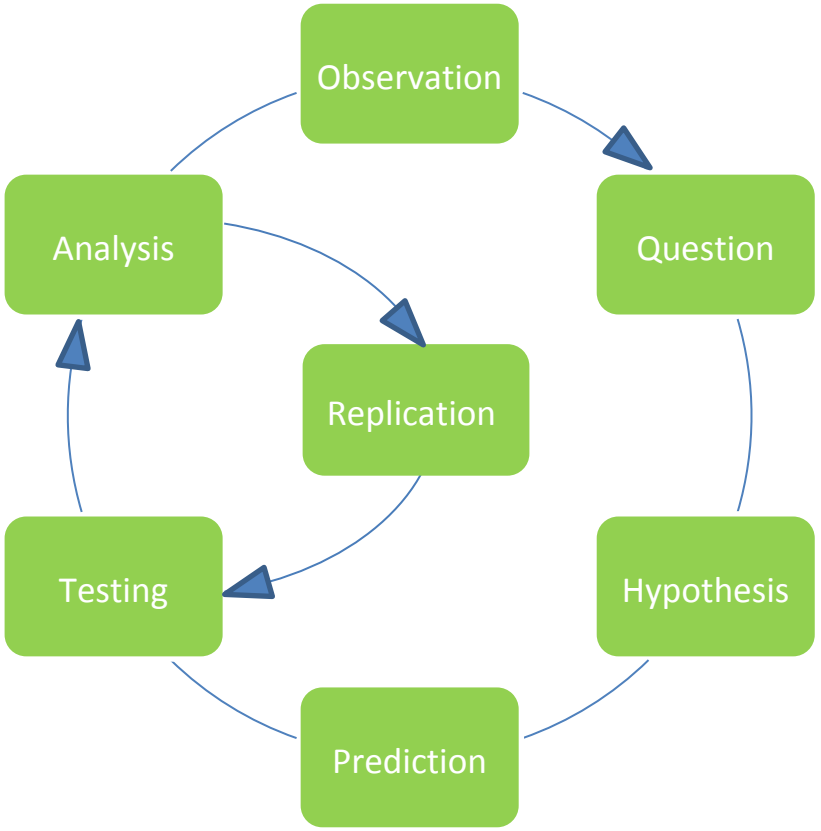
Objectives

- Understanding reproducible research
- Setting up a reproducible project
- Preregistering
- Keeping track of things
- Containing bias
- Sharing

What is the problem?

Scientific method

- Best way to learn how the world works
- Replication of findings is highest standard of evaluating evidence
- Replication of methods allows reuse and extension of new knowledge



What is the problem?

CORRESPONDENCE

Believe it or not: how much can we rely on published data on potential drug targets?

Florian Prinz, Thomas Schlange and Khusru Asadullah

A recent report by Arrowsmith noted that the success rates for new development projects in Phase II trials have fallen from 28% to 18% in recent years, with insufficient efficacy being the most frequent reason for failure (Phase II failures: 2008–2010. *Nature Rev. Drug Discov.* **10**, 328–329 (2011))[1]. This indicates the limitations of the predictivity of disease models and also that the validity of the targets being investigated is frequently questionable, which is a crucial issue to address if success rates in clinical trials are to be improved.

to 'feasible/marketable', and the financial co
of pursuing a full-blown drug discovery a
development programme for a particular t
get could ultimately be hundreds of millions
Euros. Even in the earlier stages, investmer
in activities such as high-throughput scree
ing programmes are substantial, and thus t
validity of published data on potential targ
is crucial for companies when deciding to st
novel projects.

To mitigate some of the risks of such inve
ments ultimately being wasted, most ph

LINK TO ORIGINAL ARTICLE

Power failure: why small sample size undermines the reliability of neuroscience

Katherine S. Button[1,2], John P. A. Ioannidis[3], Claire Mokrysz[1], Brian A. Nosek[4], Jonathan Flint[5], Emma S. J. Robinson[6] and Marcus R. Munafò[1]

Abstract | A study with low statistical power has a reduced chance of detecting a true effect, but it is less well appreciated that low power also reduces the likelihood that a statistically significant result reflects a true effect. Here, we show that the average statistical power of studies in the neurosciences is very low. The consequences of this include overestimates of effect size and low reproducibility of results. There are also ethical dimensions to this problem, as unreliable research is inefficient and wasteful. Improving reproducibility in neuroscience is a key priority and requires attention to well-established but often ignored methodological principles.

Open access, freely available online

Essay

Why Most Published Research Findings Are False

John P. A. Ioannidis

Summary

There is increasing concern that most current published research findings are false. The probability that a research claim is true may depend on study power and bias, the number of other studies on the same question, and, importantly, the ratio of true to no relationships among the relationships probed in each scientific field. In this framework, a research finding is less likely to be true when the studies conducted in a field are smaller; when effect sizes are smaller; when there is a greater number and lesser preselection of tested relationships; where there is greater flexibility in designs, definitions, outcomes, and analytical modes; when there is greater financial and other interest and prejudice; and when more teams are involved in a scientific field in chase of statistical significance.

factors that influence this problem and some corollaries thereof.

Modeling the Framework for False Positive Findings

Several methodologists have pointed out [9–11] that the high rate of nonreplication (lack of confirmation) of research discoveries is a consequence of the convenient, yet ill-founded strategy of claiming conclusive research findings solely on the basis of a single study assessed by formal statistical significance, typically for a *p*-value less than 0.05. Research is not most appropriately represented and summarized by *p*-values, but, unfortunately, there is a widespread notion that medical research articles

It can be proven that most claimed research findings are false.

should be interpreted based only on *p*-values. Research findings are defined here as any relationship reaching formal statistical significance, e.g., effective interventions, informative predictors, risk factors, or associations. "Negative" research is also very useful. "Negative" is actually a misnomer, and the misinterpretation is widespread. However, here we will target relationships that investigators claim exist, rather than null findings.

As has been shown previously, the probability that a research finding is indeed true depends on the prior probability of it being true (before doing the study), the statistical power of the study, and the level of statistical significance [10,11]. Consider a 2 × 2 table in which research findings are compared against the gold standard of true relationships in a scientific field. In a research field both true and false hypotheses can be made about the presence of relationships. Let R be the ratio of the number of "true relationships" to "no relationships" among those tested in the field. R is characteristic of the field and can vary a lot depending on whether the field targets highly likely relationships or searches for only one or a few true relationships among thousands and millions of hypotheses that may be postulated. Let us also consider, for computational simplicity, circumscribed fields where either there is only one true relationship (among many that can be hypothesized) or the power is similar to find any of the several existing true relationships. The pre-study probability of a relationship being true is $R/(R + 1)$. The probability of a study finding a true relationship reflects the power $1 - \beta$ (one minus the Type II error rate). The probability of claiming a relationship when none truly exists reflects the Type I error rate, α. Assuming that c relationships are being probed in the field, the expected values of the 2 × 2 table are given in Table 1. After a research finding has been claimed based on achieving formal statistical significance, the post-study probability that it is true is the positive predictive value, PPV. The PPV is also the complementary probability of what Wacholder et al. have called the false positive report probability [10]. According to the 2 × 2 table, one gets $PPV = (1 - \beta)R/(R - \beta R + \alpha)$. A research finding is thus

Citation: Ioannidis JPA (2005) Why most published research findings are false. PLoS Med 2(8): e124.

Abbreviation: PPV, positive predictive value

John P. A. Ioannidis is in the Department of Hygiene and Epidemiology, University of Ioannina School of Medicine, Ioannina, Greece, and Institute for Clinical Research and Health Policy Studies, Department of Medicine, Tufts-New England Medical Center, Tufts University School of Medicine, Boston, Massachusetts, United States of America. E-mail: jioannid@cc.uoi.gr

Competing Interests: The author has declared that no competing interests exist.

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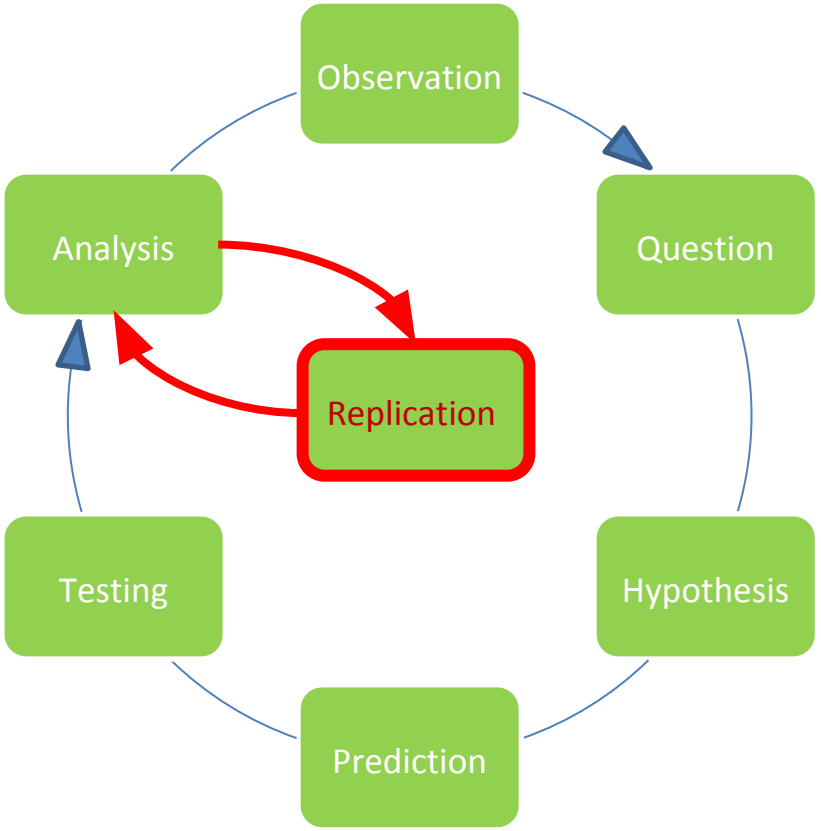
What is reproducibility?

- **Computational reproducibility**

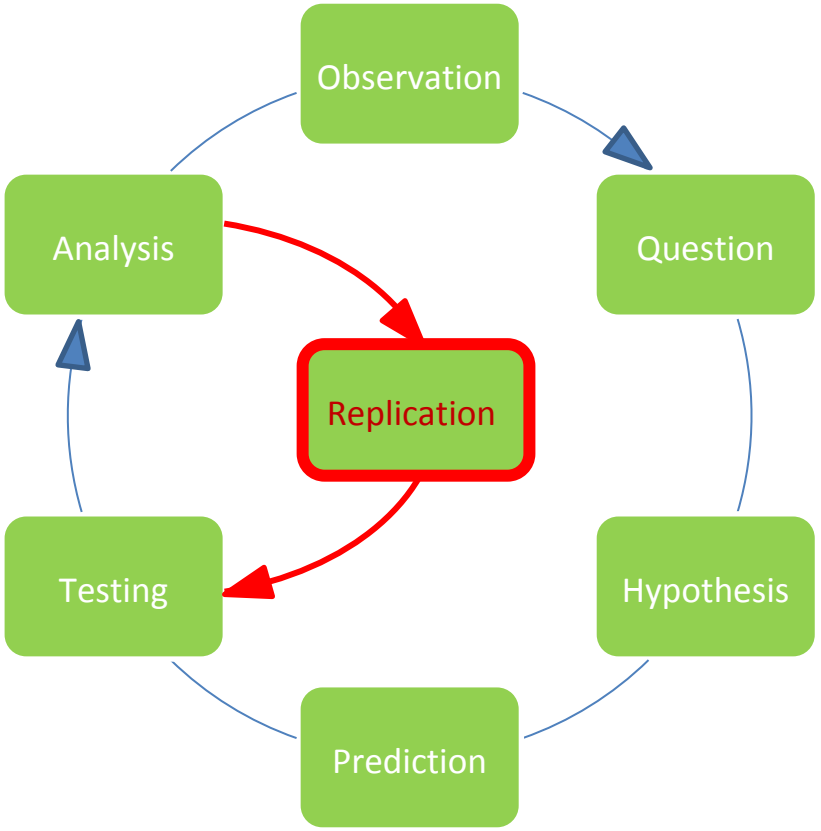
Scientific method



What is reproducibility?

- Computational reproducibility
- **Empirical reproducibility**

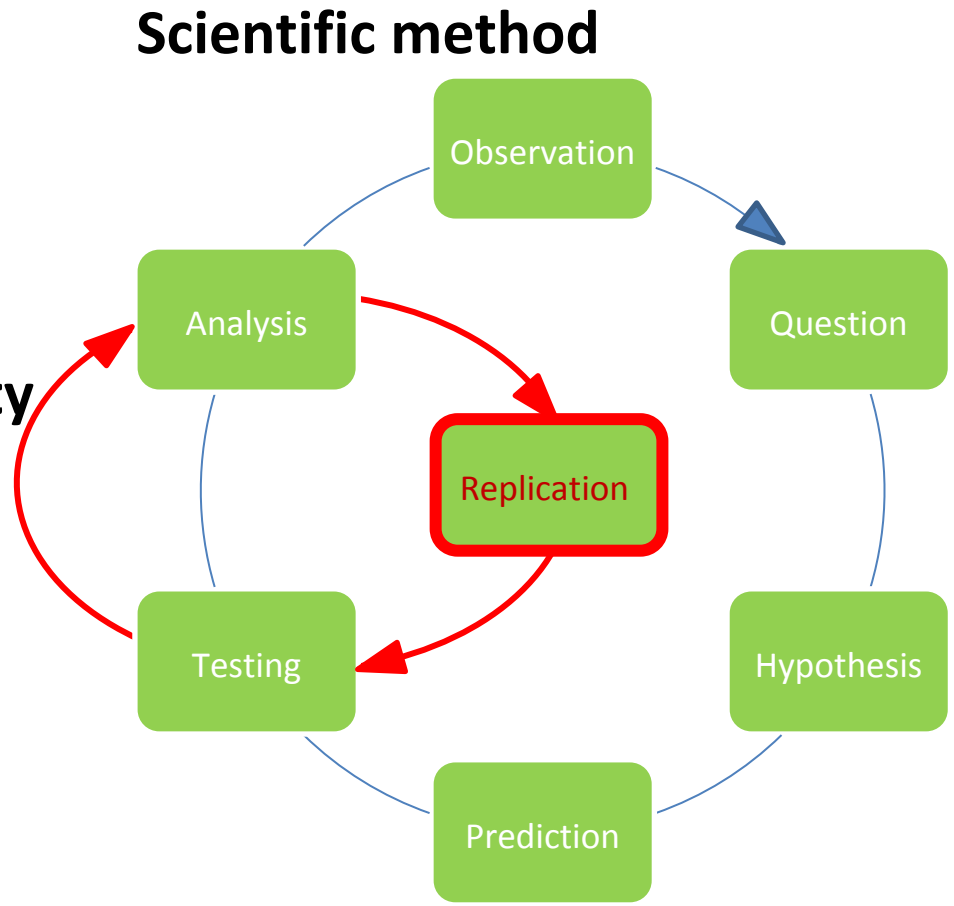
Scientific method



What is reproducibility?

- Computational reproducibility
- Empirical reproducibility
- **Conceptual reproducibility**

New data



What are the barriers?

What are the barriers?

- Statistical
  - Low power
  - Researcher degrees of freedom

- Transparency
  - Poor documentation
  - Poor reporting
  - Lack of sharing

Why practice reproducibility?

The idealist

- **Shoulders of giants!**
- Validates scientific knowledge
- Allows others to build on your findings
- Improved transparency
- Increased transfer of knowledge
- Increased utility of your data + methods

The pragmatist

- Increased efficiency
- Reduces false leads based on irreproducible findings
- Data sharing citation advantage (Piwowar 2013)
- "It takes some effort to organize your research to be reproducible… the **principal beneficiary is generally the author herself**."- Schwab & Claerbout

How can you make your research reproducible?

1. Plan for reproducibility before you start

- Create a study plan
- Set-up a reproducible project
- Preregistration
- Informative file naming

2. Keep track of things

- Version control
- Documentation

3. Contain bias

- Reporting

4. Archive + share your materials

1. Plan for reproducibility before you start

Create a study plan

- **Create a study plan** before you gather your data
- Create a data management plan
- Begins documentation early
- Shows evolution of study

How?

- Research questions
- Study design
  - Type of design
  - Sampling
  - Power and sample size
  - Randomization?
- Variables measured
  - Meaningful effect size
- Variables constructed
  - Data processing
- Data management plan
- Analysis plan
- Sharing plan

1. Plan for reproducibility before you start

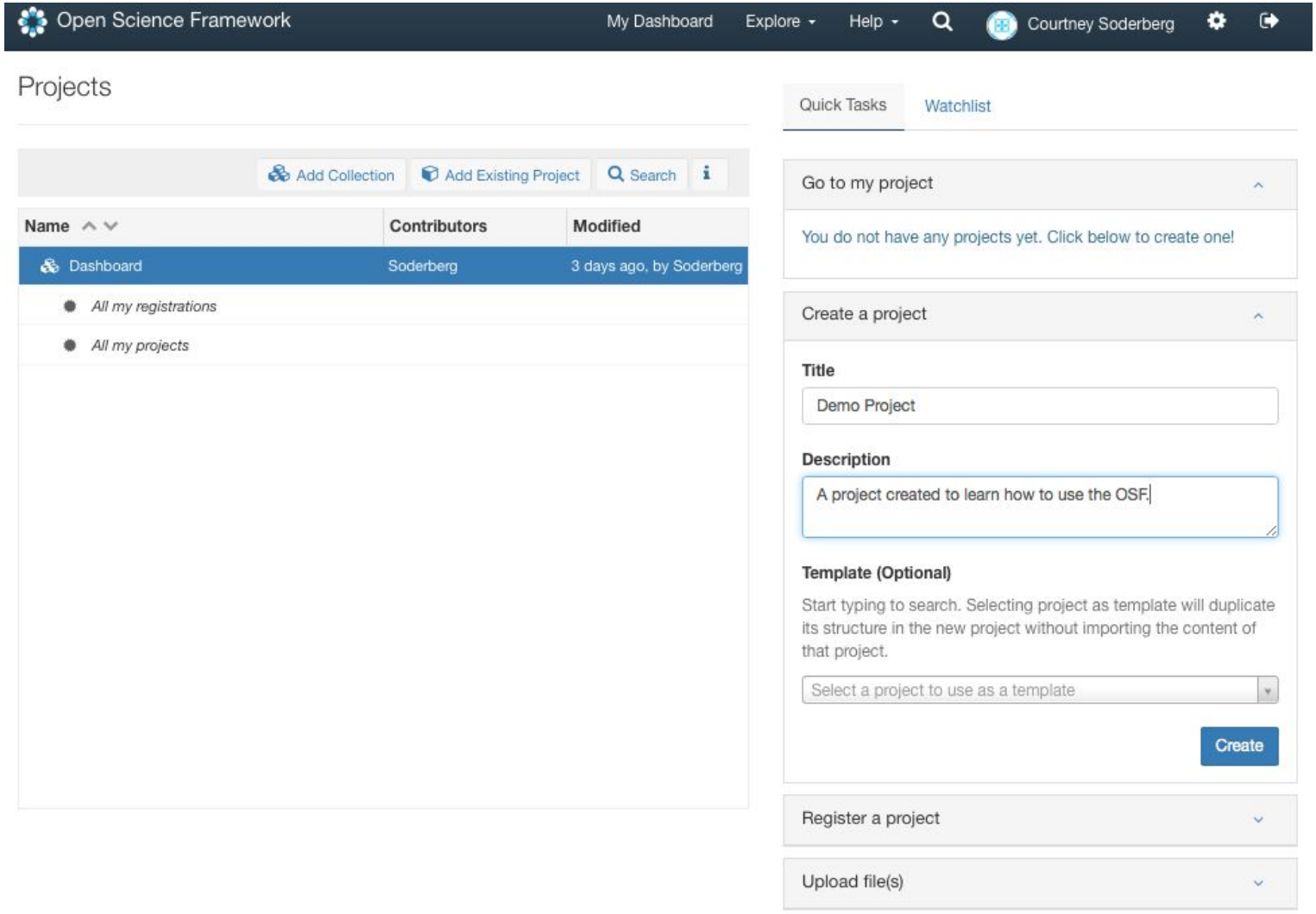
Set-up a reproducible project

- **Set-up a centralized location for project management**
- Organization is especially important for collaboration
- Easily find the most recent file version
- Eases transition between lab members
- Allows for backup and version control

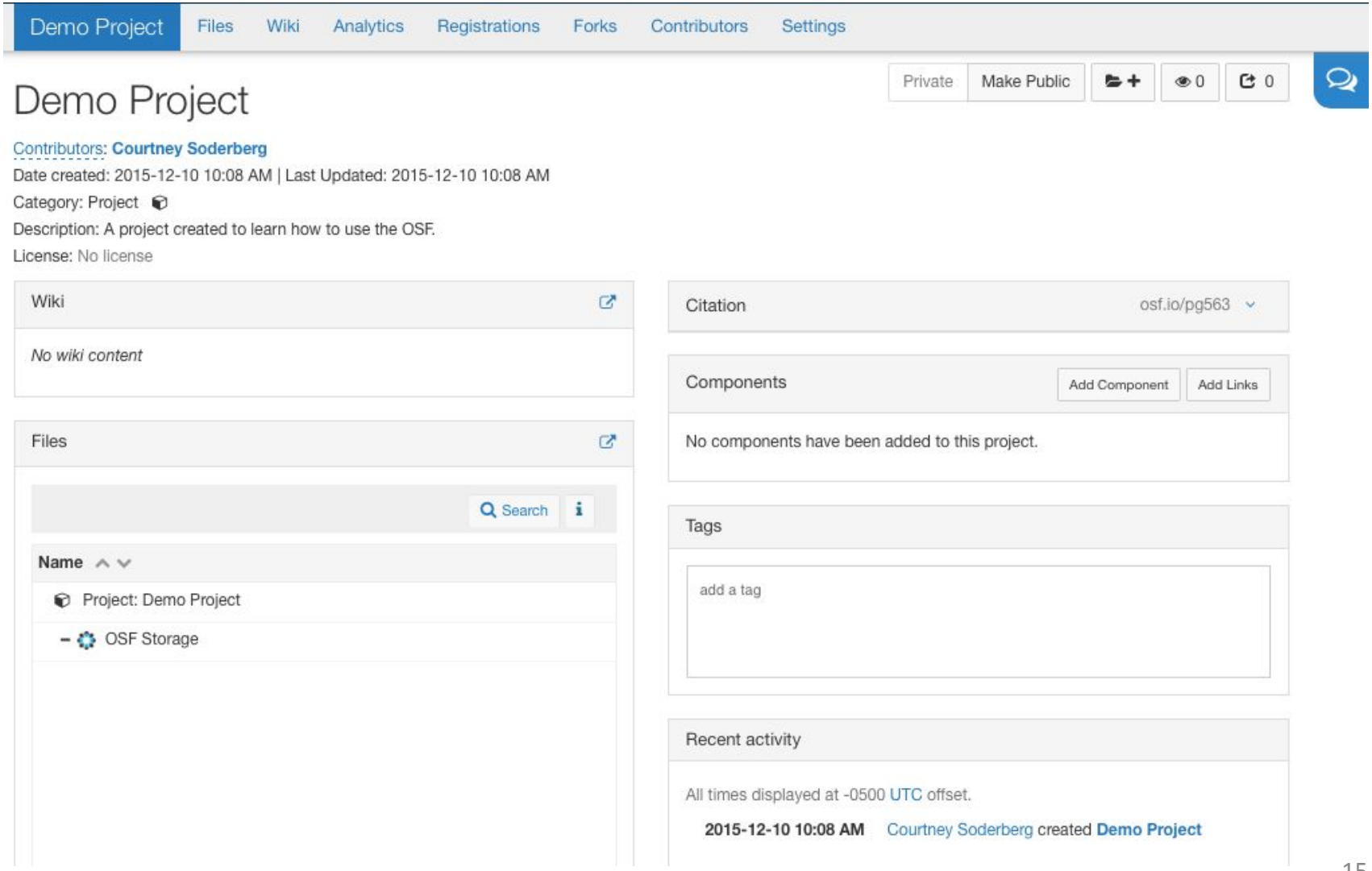
How?

https://osf.io/

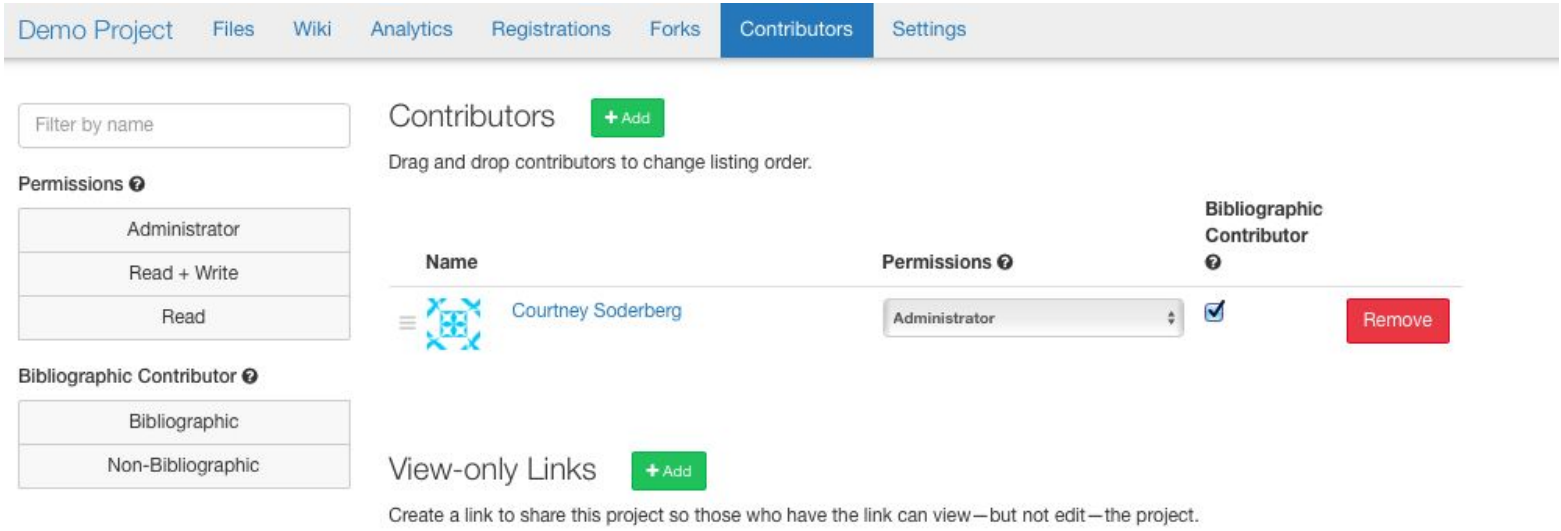
1. Create an OSF project



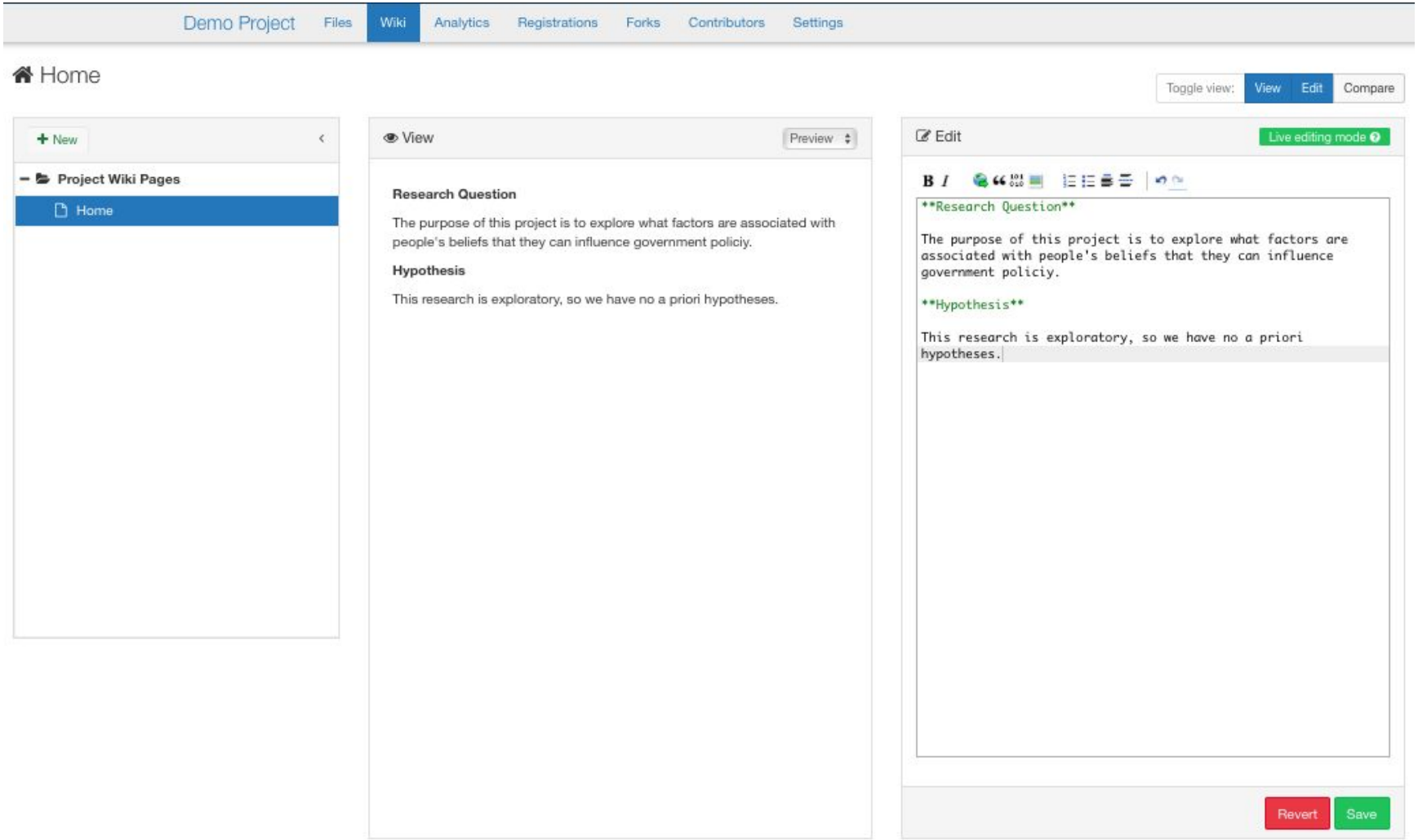
1. Wiki, file tree, components, citation, GUID



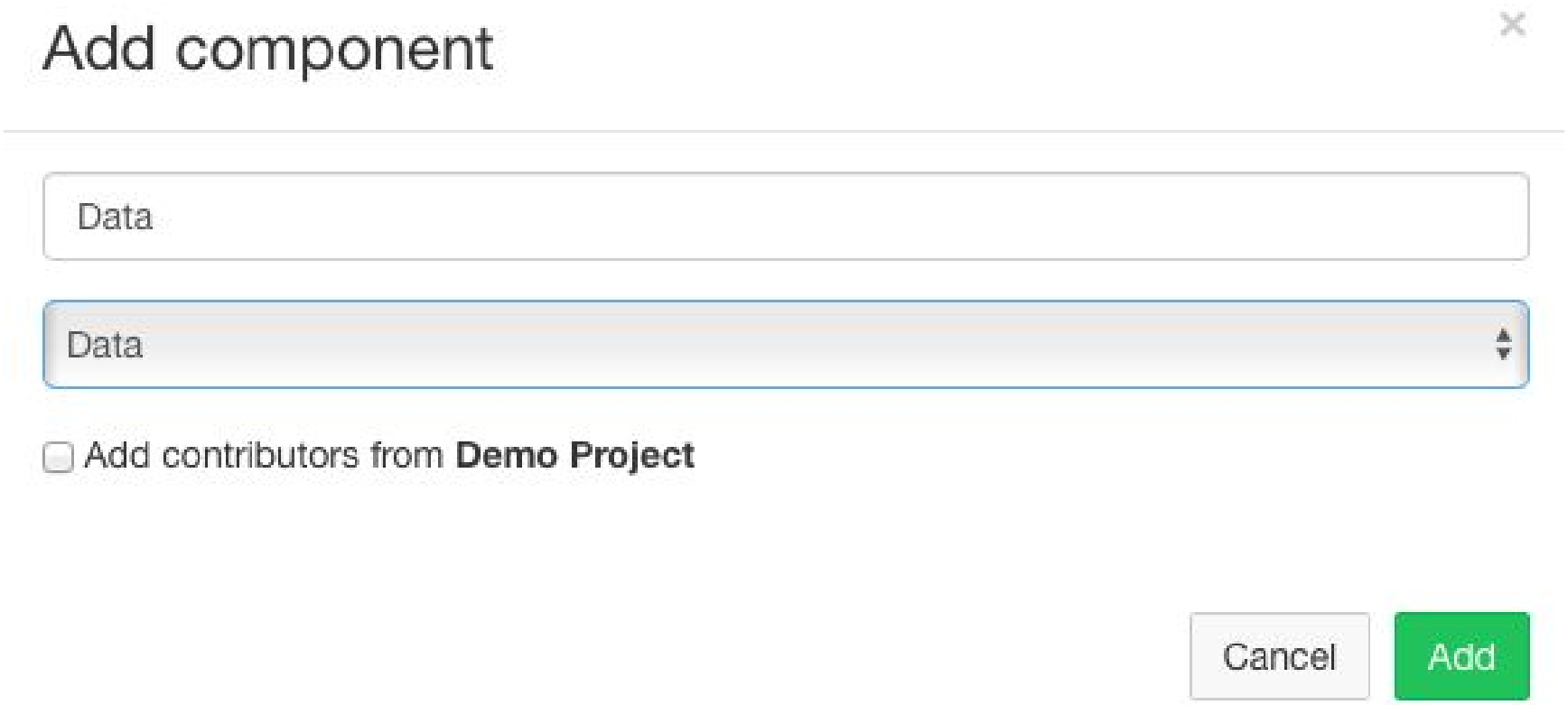
1. Giving contributors access



1. Creating a wiki



1. Adding organizational structure - components



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- Reporting

4. Archive + share your materials

1. Plan for reproducibility before you start

Preregister your study plan

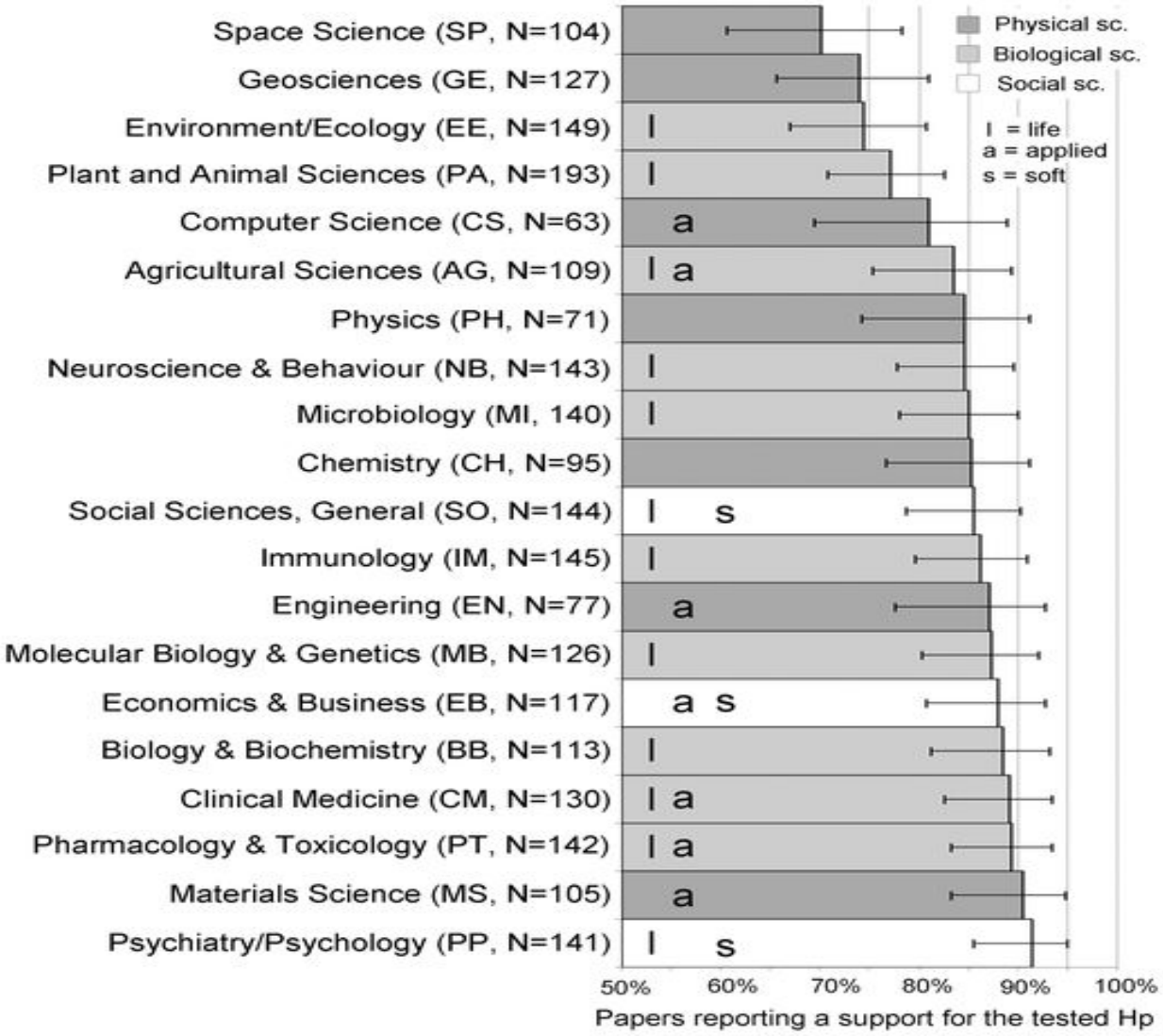
- **Preregister your study plan** before you look at your data
- Distinguishes *a priori* design decisions from *post hoc*
- Counters selective reporting and outcome reporting bias
- Preregistration of all study plans helps counter publication bias

PROSPERO

ClinicalTrials.gov

AEA RCT Registry

Publication bias



Fanelli D (2010) “Positive” Results Increase Down the Hierarchy of the Sciences. PLoS ONE 5(4): e10068.

1. Plan for reproducibility before you start

Analysis plan

- **Preregister your analysis plan** before you look at your data
- Defines your confirmatory analyses
- Decreases researcher degrees of freedom

How?

- Define data analysis set
- Statistical analyses
  - Primary
  - Secondary
  - Exploratory
- Missing data
- Outliers
- Multiplicity
- Subgroups + covariates

(Adams-Huet and Ahn, 2009)

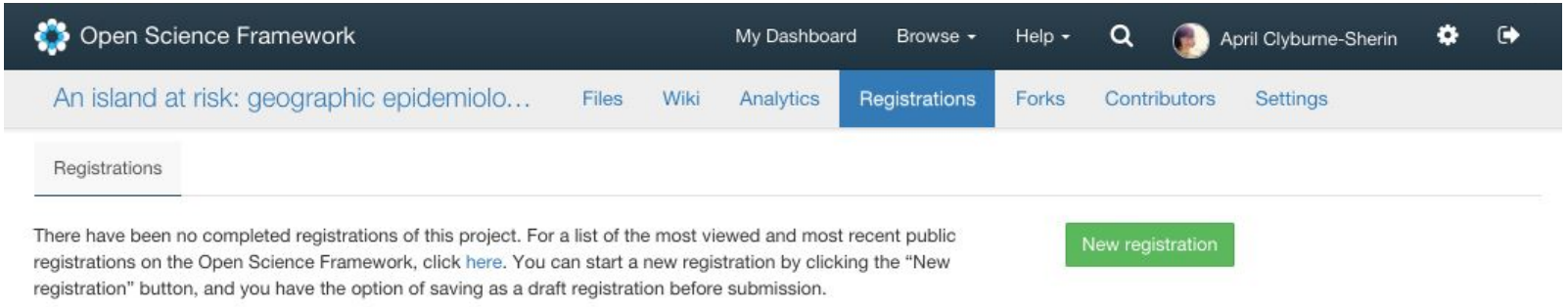
Researcher degrees of freedom

Table 1. Likelihood of Obtaining a False-Positive Result

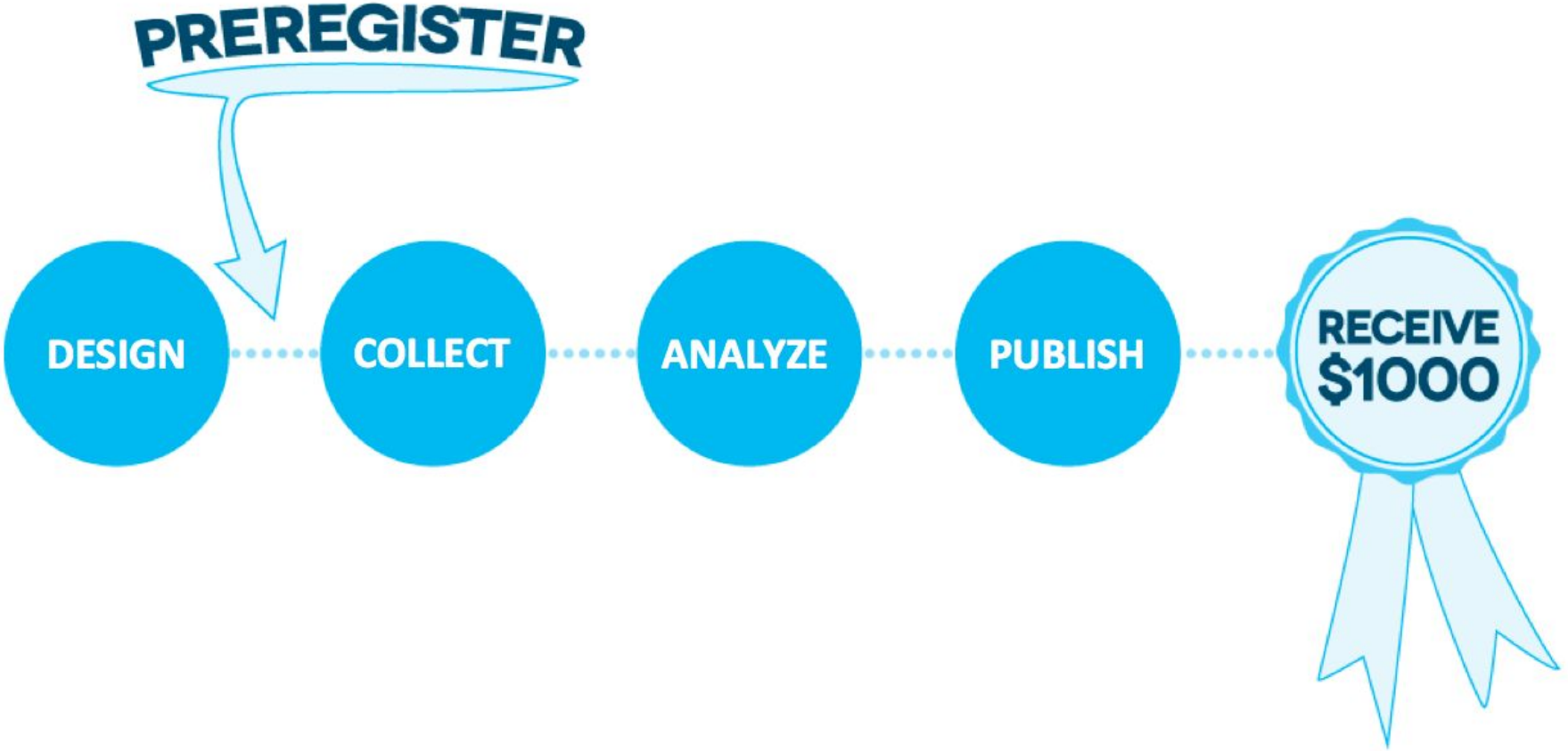
	Significance level		
Researcher degrees of freedom	$p < .1$	$p < .05$	$p < .01$
Situation A: two dependent variables ($r = .50$)	17.8%	9.5%	2.2%
Situation B: addition of 10 more observations per cell	14.5%	7.7%	1.6%
Situation C: controlling for gender or interaction of gender with treatment	21.6%	11.7%	2.7%
Situation D: dropping (or not dropping) one of three conditions	23.2%	12.6%	2.8%
Combine Situations A and B	26.0%	14.4%	3.3%
Combine Situations A, B, and C	50.9%	30.9%	8.4%
Combine Situations A, B, C, and D	81.5%	60.7%	21.5%

Simmons, Nelson, & Simonsohn (2012)

1. How to preregister



The Preregistration Challenge



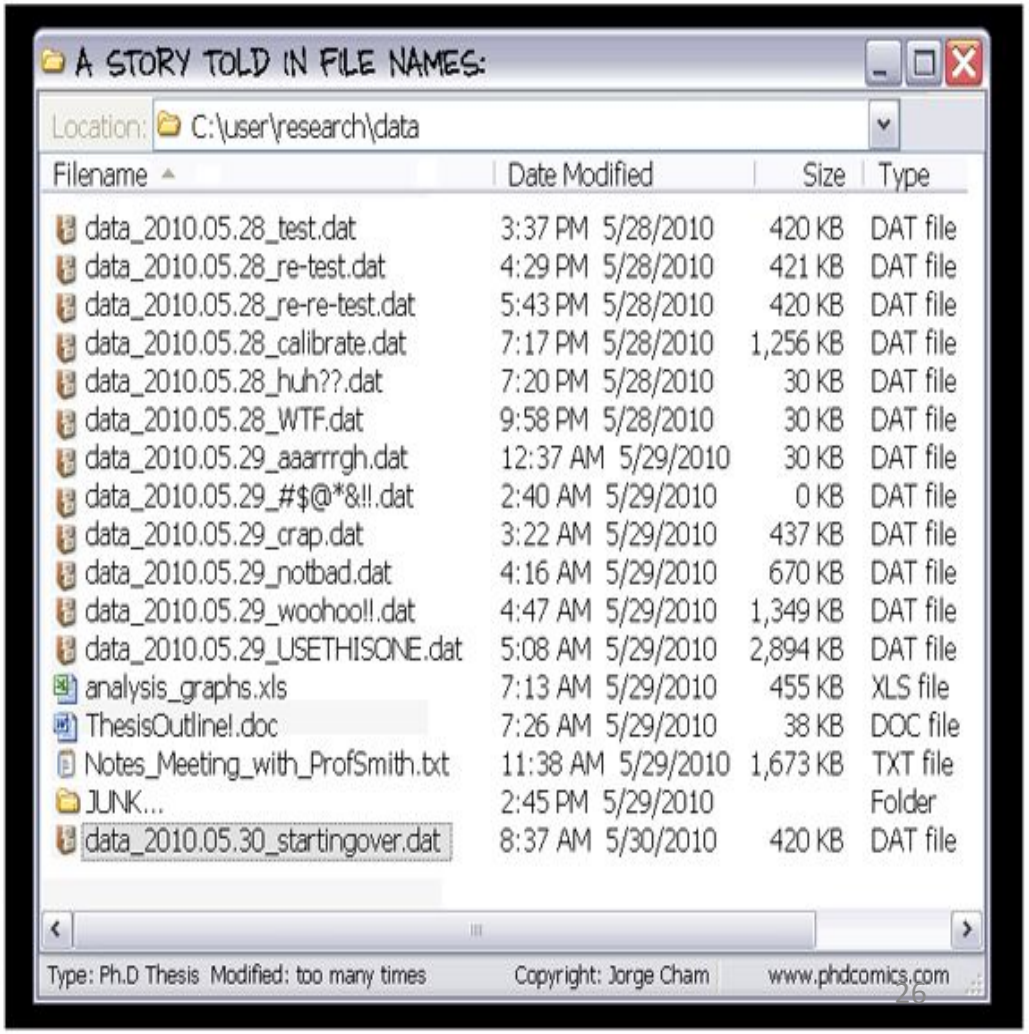
$1000 incentive to preregister

http://cos.io/prereg

1. Plan for reproducibility before you start

Informative name + location

- Plan your file naming + location system *a priori*
- Names and locations should be distinctive, consistent, and informative:
  - What it is
  - Why it exists
  - How it relates to other files



1. Plan for reproducibility before you start

Informative name + location

- **The rules don't matter. That you have rules matters.**
- Make it machine readable:
  - Default ordering
  - Use of meaningful deliminators and tags
  - Example: use "_" and "-" to store metadata in name (eg, YYYY-MM-DD_assay_sample-set_well)
- Make it human readable:
  - Choose self-explanatory names and locations

2. Keep track of things

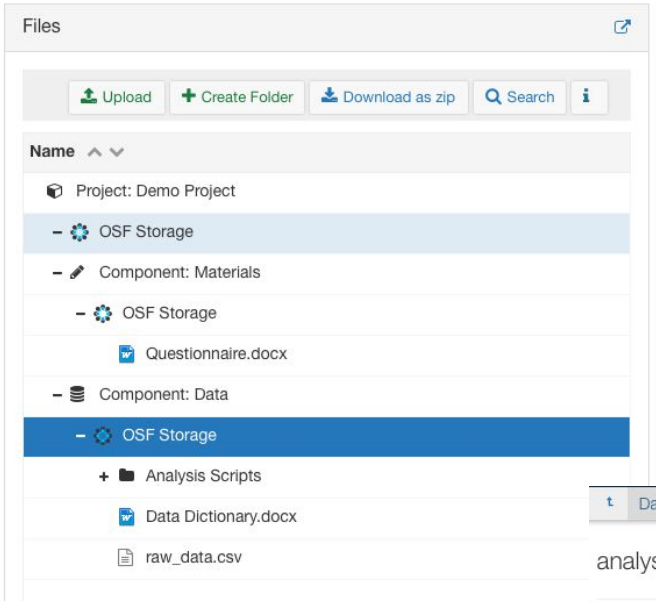
Version control

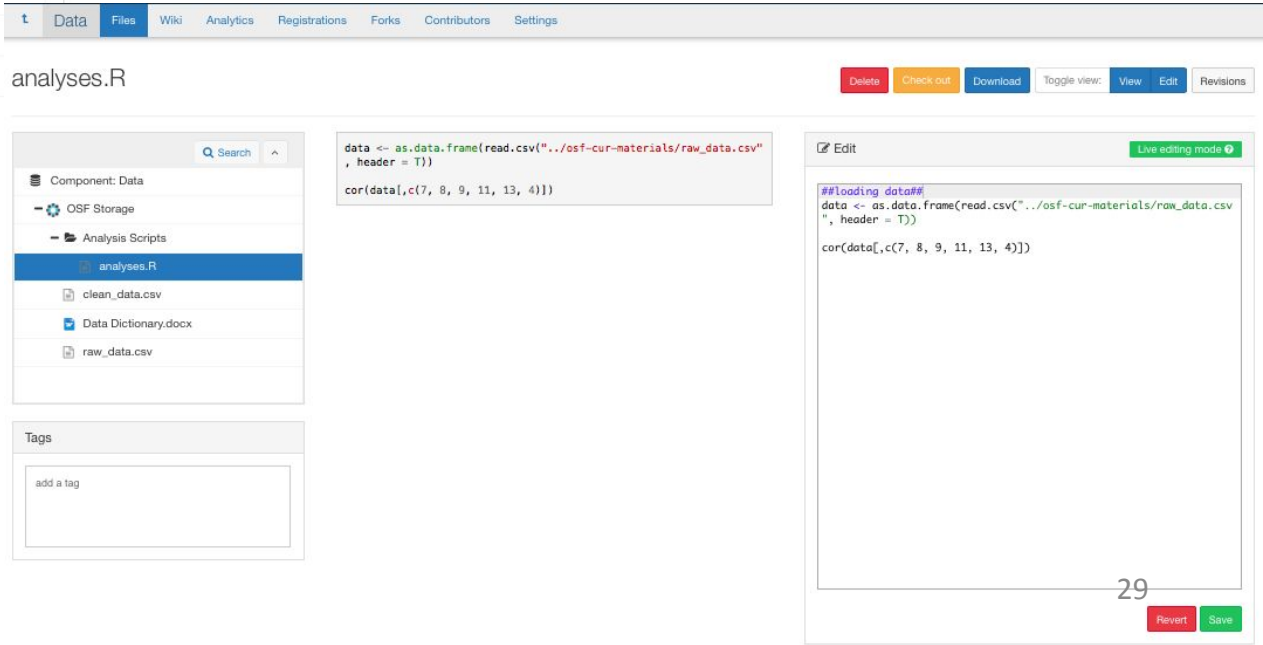
- **Track your changes**
- Everything created manually should use version control
- Tracks changes to files, code, metadata
- Allows you to revert to old versions
- Make incremental changes: commit early, commit often
- Git / GitHub / BitBucket

Version control for data

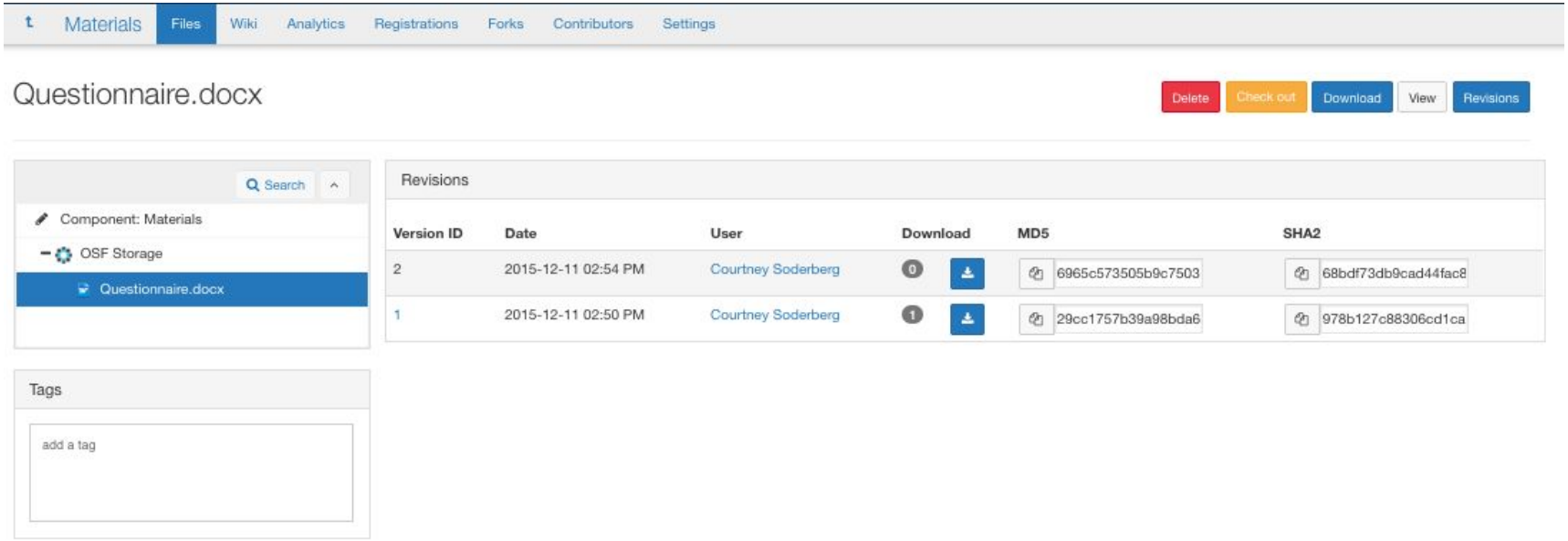
- Metadata should be version controlled

2. Version control





2. Version control

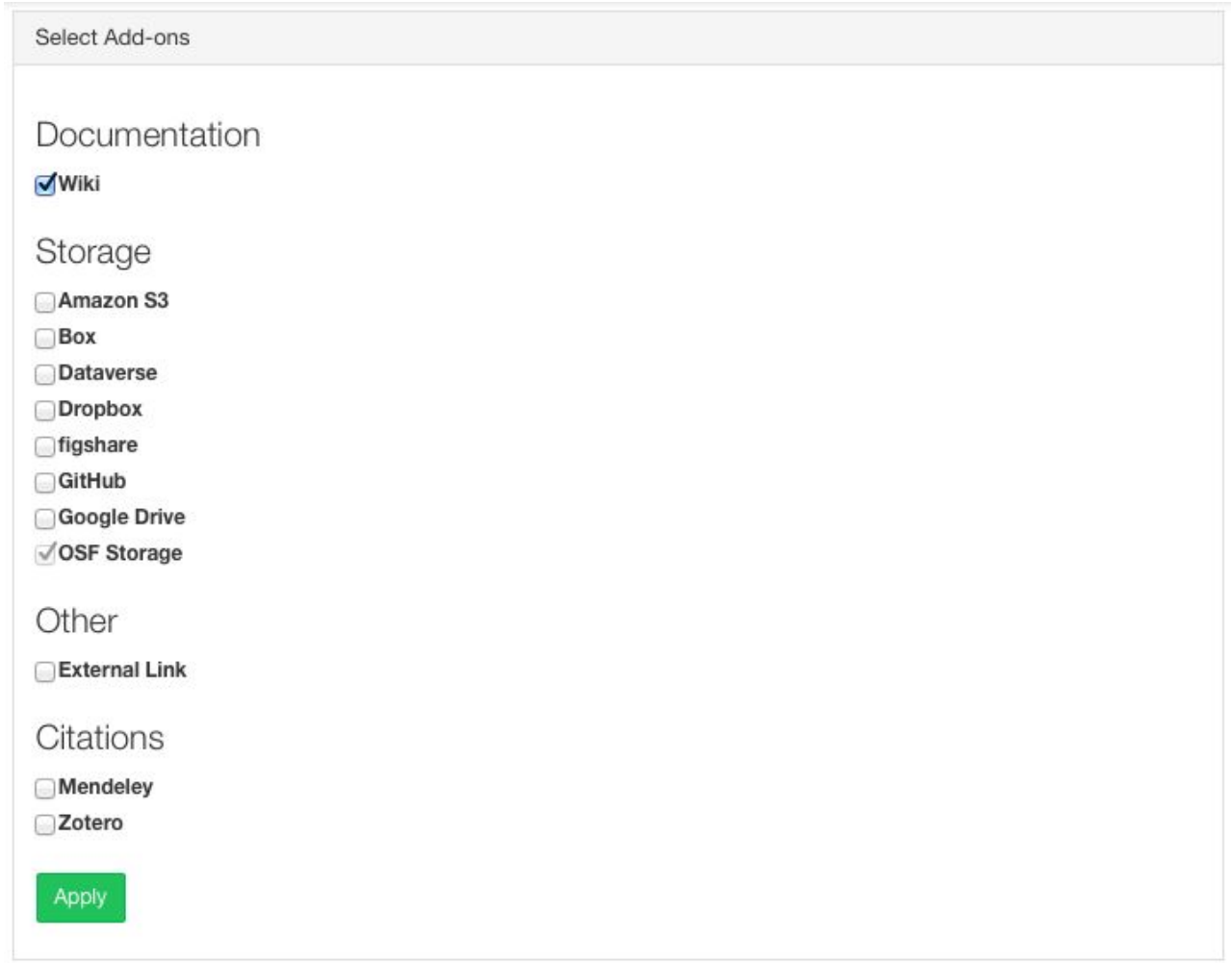


2. Keep track of things

Documentation

- **Document everything done by hand**
- Document your software environment (eg, dependencies, libraries, sessionInfo () in R)
- Everything done by hand or not automated from data and code should be precisely documented:
  - README files
- Make raw data read only
  - You won't edit it by accident
  - Forces you to document or code data processing
- Document in code comments

1. Add-ons


Select Add-ons
Documentation
Wiki
Storage
Amazon S3
Box
Dataverse
Dropbox
figshare
GitHub
Google Drive
OSF Storage
Other
External Link
Citations
Mendeley
Zotero
Apply

3. Contain bias

Reporting

- **Report transparently + completely**
- Transparently means:
  - Readers can use the findings
  - Replication is possible
  - Users are not misled
  - Findings can be pooled in meta-analyses
- Completely means:
  - All results are reported, no matter their direction or statistical significance

How?

- Avoid HARKing: Hypothesizing After the Results are Known
- Report all deviations from your study plan
- Report which decisions were made after looking at the data

4. Archive + share your materials

Share your materials

- **Where doesn't matter.**
  That you share matters.
- Get credit for your code, your data, your methods
- Increase the impact of your research

Open Science Framework

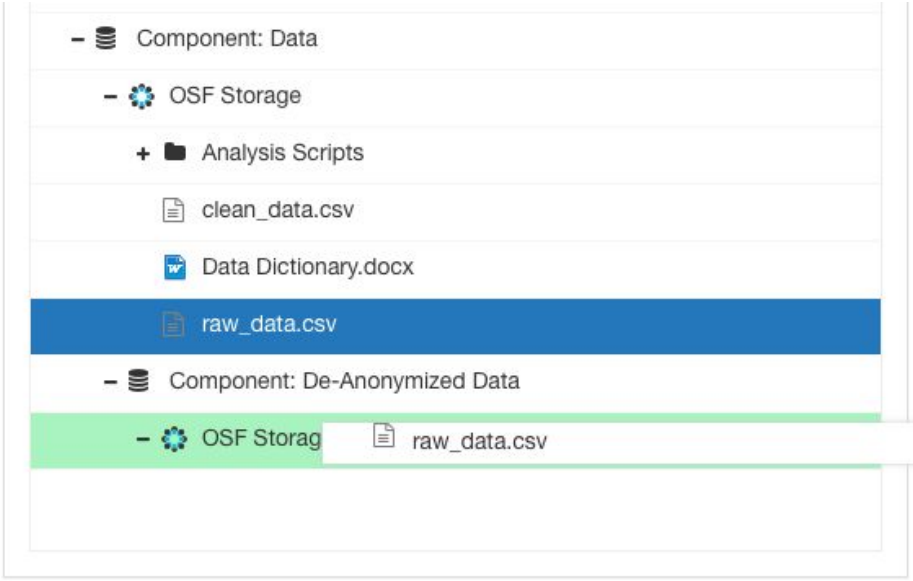
The Dataverse Project

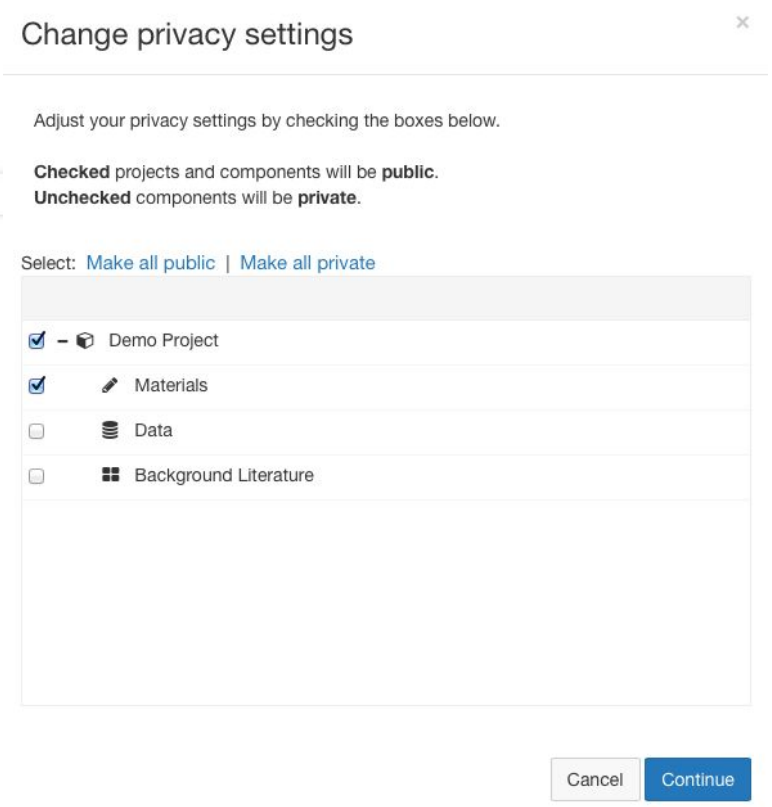
figshare
credit for all your research

GitHub

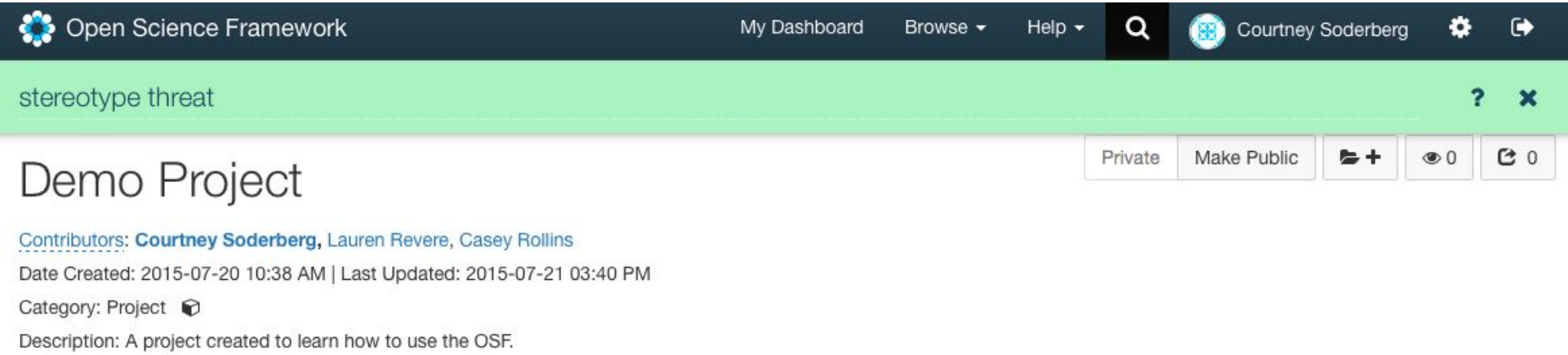
DRYAD

4. Share your work

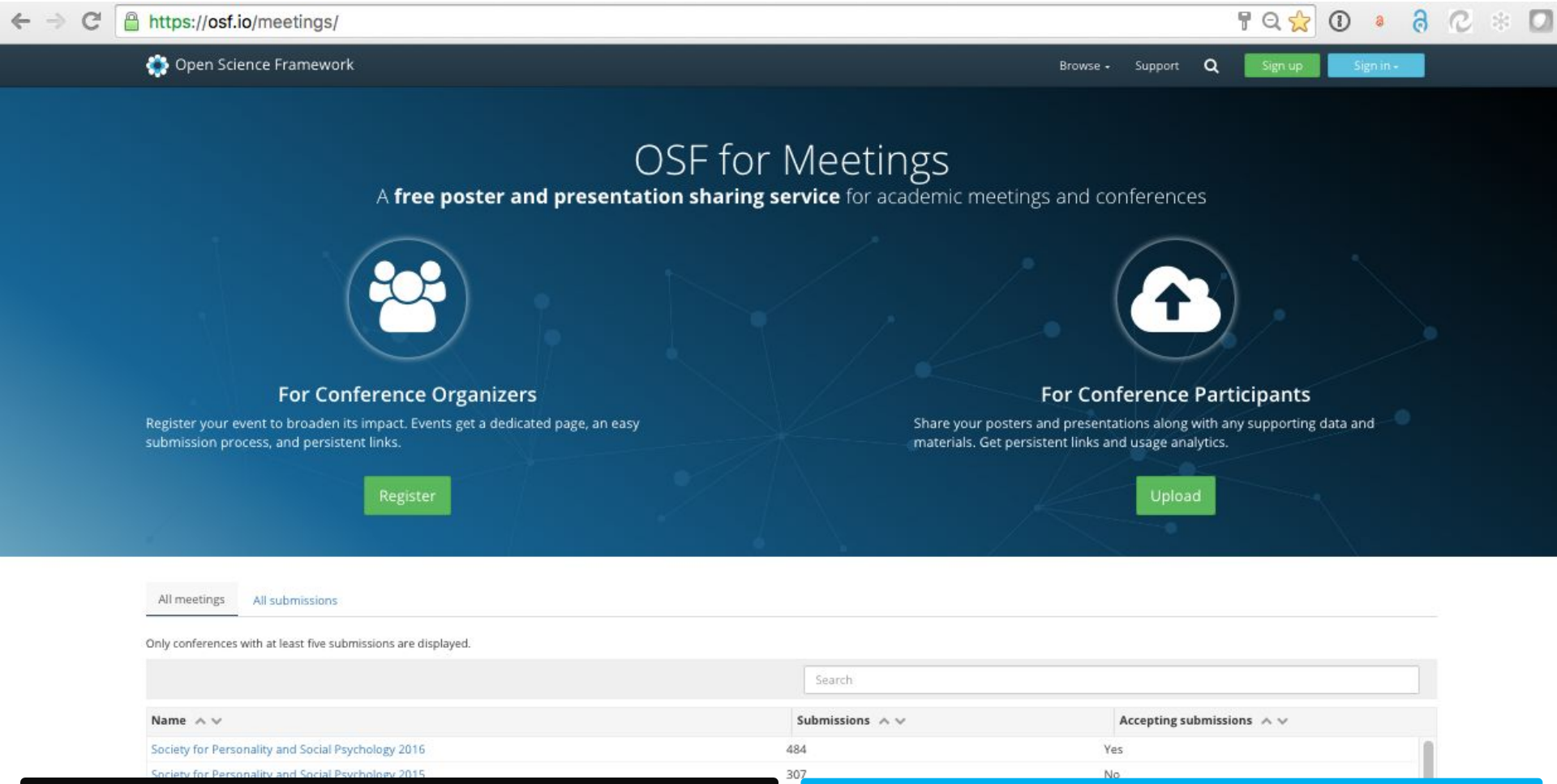




4. Increasing discoverability



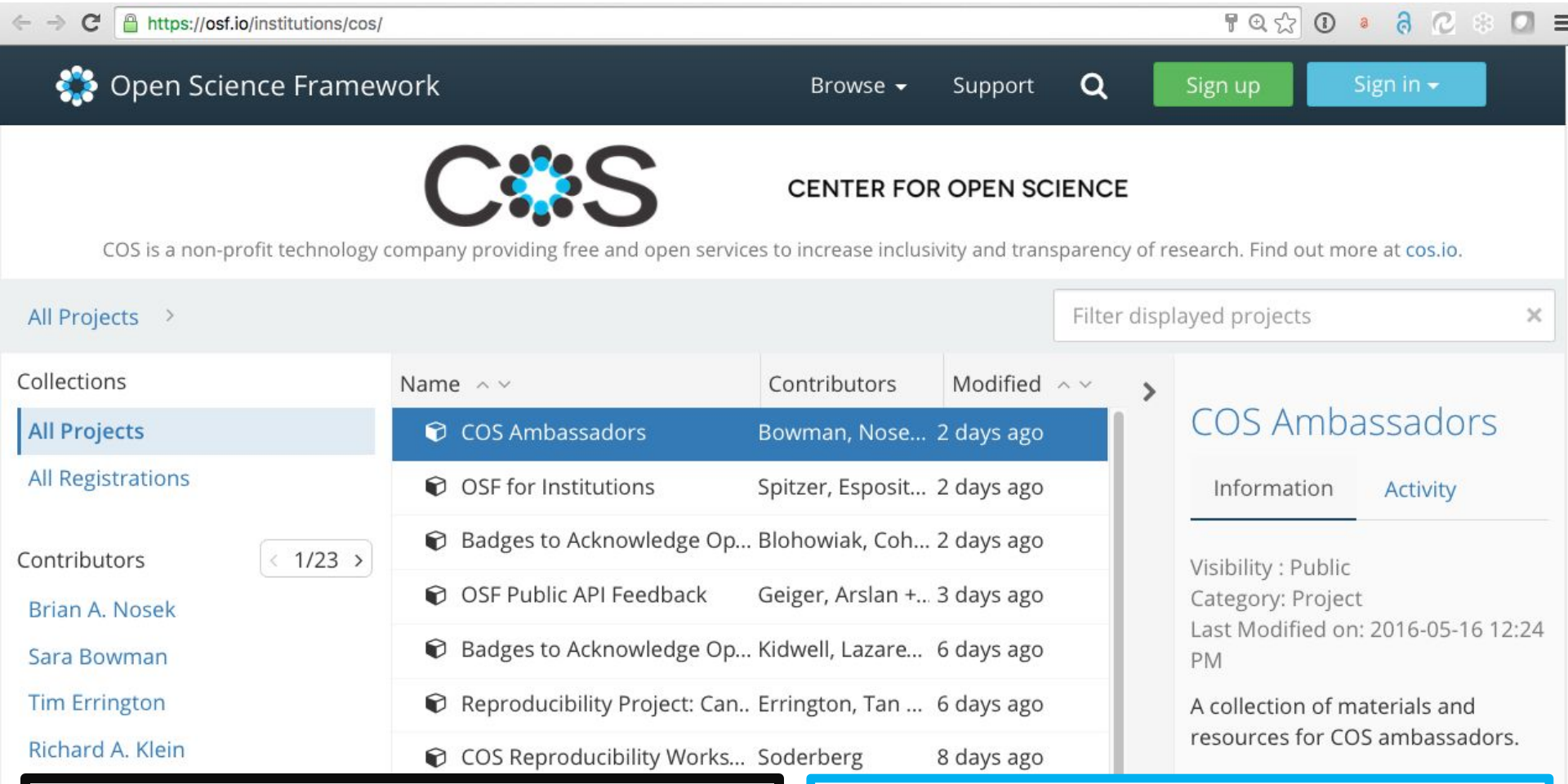
OSF for Meetings



free poster + presentation service

https://osf.io/meetings

OSF for Institutions



integration with local research services

https://osf.io/institutions/cos

Transparency and Openness Promotion (TOP) Guidelines

http://cos.io/top

Citation standards

Data transparency

Analytic methods (code) transparency

Research materials transparency

Design and analysis transparency

Preregistration of studies

Preregistration of analysis plans

Replication

Modular standards

Low barrier to entry

Discipline agnostic

http://cos.io/top

	LEVEL 1	LEVEL 2	LEVEL 3
Citation standards			
Data transparency			
Analytic methods (code) transparency			
Research materials transparency			
Design and analysis transparency			
Preregistration of studies			
Preregistration of analysis plans			
Replication			

Level 1 Disclose

Level 2 Require

Level 3 Verify

http://cos.io/top

	LEVEL 1	LEVEL 2	LEVEL 3
Citation standards	Journal describes citation of data in guidelines to authors with clear rules and examples.	Article provides appropriate citation for data and materials used, consistent with journal's author guidelines.	Article is not published until appropriate citation for data and materials is provided that follows journal's author guidelines.
Data transparency	Article states whether data are available and, if so, where to access them.	Data must be posted to a trusted repository. Exceptions must be identified at article submission.	Data must be posted to a trusted repository, and reported analyses will be reproduced independently before publication.
Analytic methods (code) transparency	Article states whether code is available and, if so, where to access them.	Code must be posted to a trusted repository. Exceptions must be identified at article submission.	Code must be posted to a trusted repository, and reported analyses will be reproduced independently before publication.
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Design and analysis transparency	Journal articulates design transparency standards.	Journal requires adherence to design transparency standards for review and publication.	Journal requires and enforces adherence to design transparency standards for review and publication.
Preregistration of studies	Journal encourages preregistration of studies and provides link in article to preregistration if it exists.	Journal encourages preregistration of studies and provides link in article and certification of meeting preregistration badge requirements.	Journal requires preregistration of studies and provides link and badge in article to meeting requirements.
Preregistration of analysis plans	Journal encourages preanalysis plans and provides link in article to registered analysis plan if it exists.	Journal encourages preanalysis plans and provides link in article and certification of meeting registered analysis plan badge requirements.	Journal requires preregistration of studies with analysis plans and provides link and badge in article to meeting requirements.
Replication	Journal encourages submission of replication studies.	Journal encourages submission of replication studies and conducts blind review of results.	Journal uses Registered Reports as a submission option for replication studies with peer review before observing the study outcomes.

"*The policy of the __ is to publish papers where authors indicate whether the data, methods used in the analysis, and materials used to conduct the research will be made available to any researcher for purposes of reproducing the results or replicating the procedure.*

- *Authors must, in acknowledgments or the first footnote, indicate if they will or will not make their data, analytic methods, and study materials available to other researchers.*
- *If an author agrees to make materials available, the author must specify where that material will be available."*

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“The policy of the _____ is to publish papers only if the data used to conduct the research are clearly and precisely documented and are maximally available to any researcher for purposes of reproducing the results or replicating the procedure.

Details of:

- *What must be shared*
- *Legal and Ethical Exceptions – Disclosure at onset of review*
- *Using trusted repositories”*

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Design and analysis transparency	Journal articulates design transparency standards.	Journal requires adherence to design transparency standards for review and publication.	Journal requires and enforces adherence to design transparency standards for review and publication.
Preregistration of studies	Journal encourages preregistration of studies and provides link in article to preregistration if it exists.	Journal encourages preregistration of studies and provides link in article and certification of meeting preregistration badge requirements.	Journal requires preregistration of studies and provides link and badge in article to meeting requirements.
Preregistration of analysis plans	Journal encourages preanalysis plans and provides link in article to registered analysis plan if it exists.	Journal encourages preanalysis plans and provides link in article and certification of meeting registered analysis plan badge requirements.	Journal requires preregistration of studies with analysis plans and provides link and badge in article to meeting requirements.
Replication	Journal encourages submission of replication studies.	Journal encourages submission of replication studies and conducts blind review of results.	Journal uses Registered Reports as a submission option for replication studies with peer review before observing the study outcomes.

"... are maximally available to any researcher for purposes of reproducing the results or replicating the procedure.

All materials supporting the claims made by the author must be made available to the journal prior to publication. The journal, or an entity acting on behalf of the journal, will verify that the findings are replicable using the author's data and methods of analysis. Failure to replicate at this stage may result in the paper not being published."

http://cos.io/top

539 Journals
59 Organizations

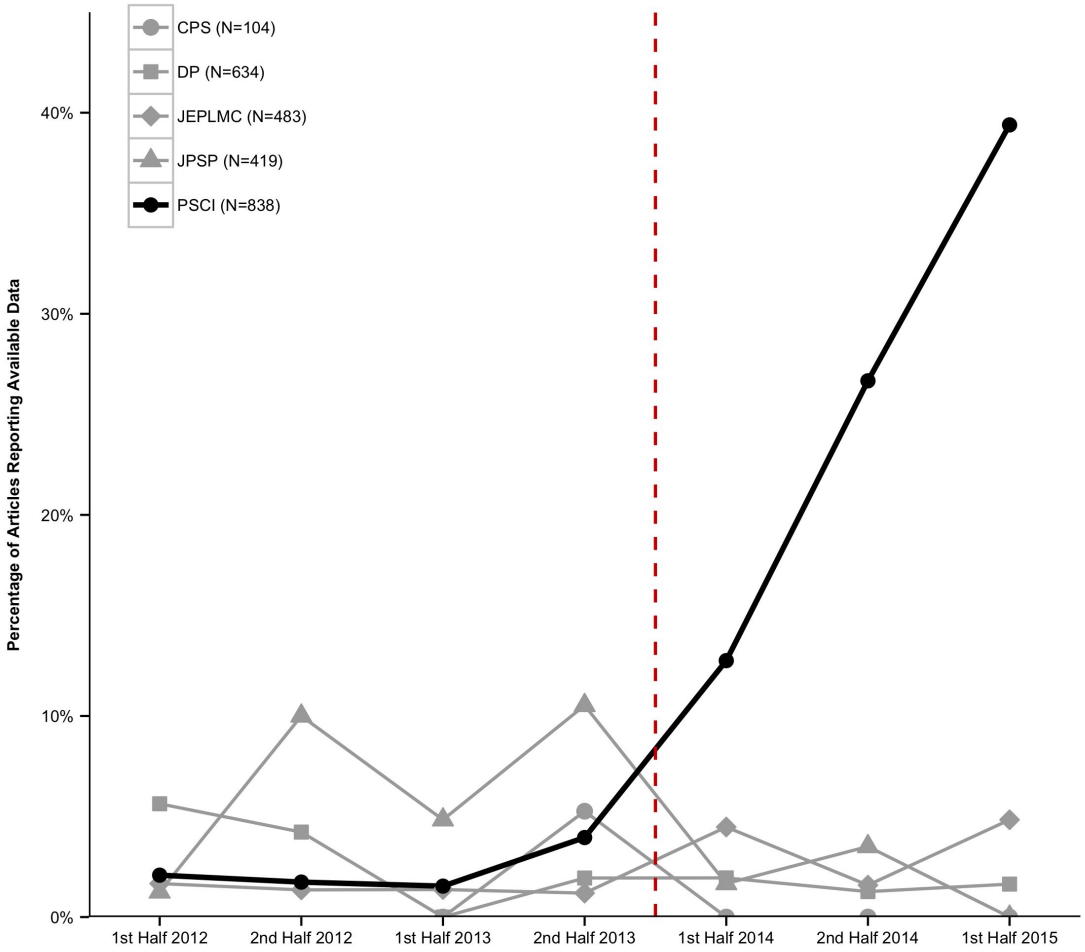
http://cos.io/top

Badges for Open Practices

article signals open behaviour

https://osf.io/rfgdw

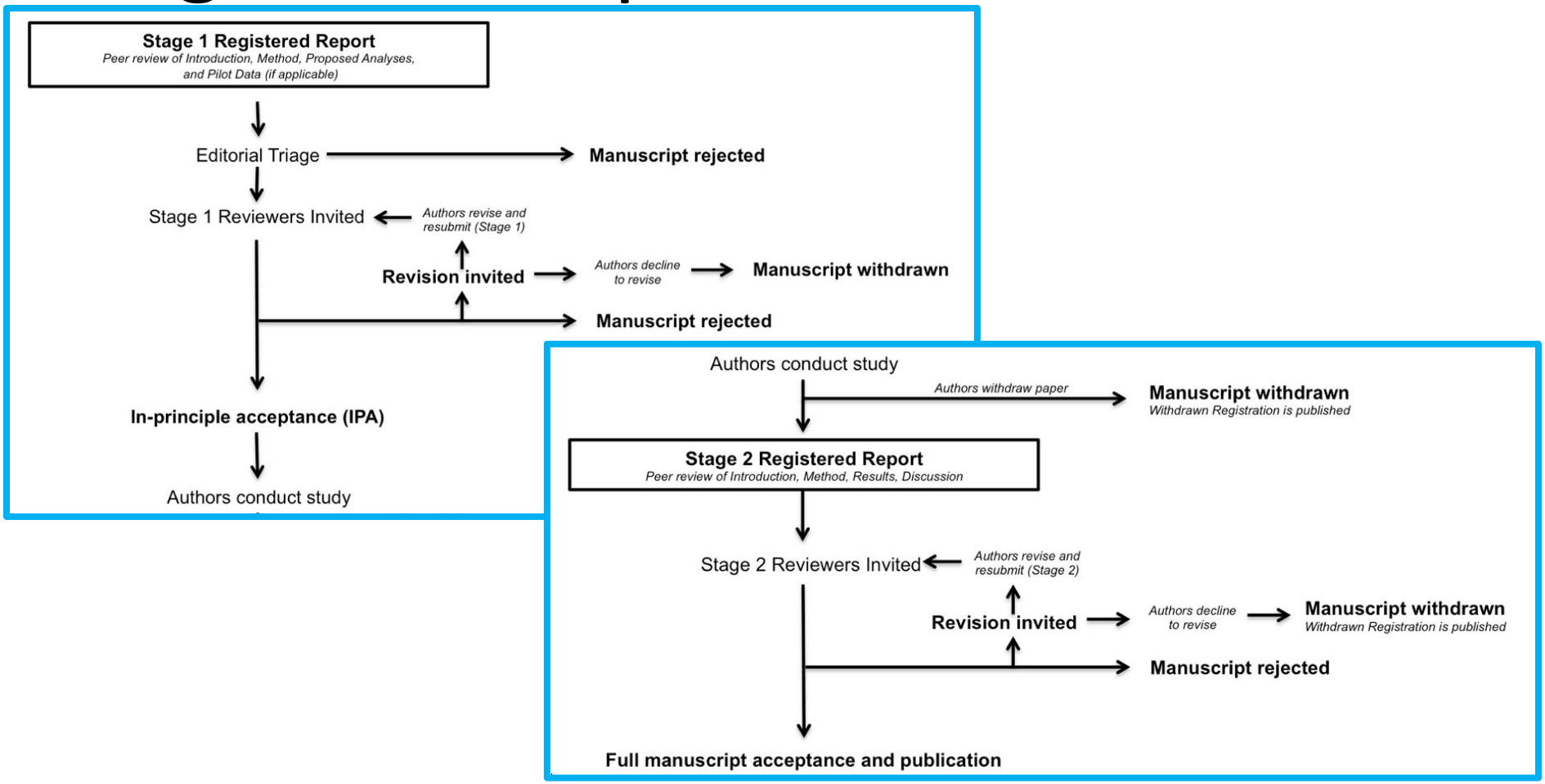
Case Study: Psychological Science



article signals open behaviour

https://osf.io/rfgdw

Registered Reports



system to reward rigor rather than findings

https://osf.io/8mpji

Reproducibility training

Statistical & Methodological Consulting

Scientists can improve the replicability of their own work through careful documentation, adherence to standards, and the use of open tools. We answer questions and provide training on open and reproducible tools, methodologies, and workflows. Some examples:

- ✔Using R
- ✔Conducting power analyses
- ✔Using the OSF
- ✔Learning Github
- ✔Conducting meta-analyses
- ✔Preregistering analysis plans

This service is provided in partnership with the Berkeley Initiative for Transparency in the Social Sciences (BITSS)

Request a Consultation

Request a Workshop

Receive Updates on our Services

free stats + methods training

http://cos.io/stats_consulting

How can you make your research reproducible?

1. Plan for reproducibility before you start

- **Create a study plan** – Begin documentation at study inception
- **Set-up a reproducible project** – Centralize and organize your project management
- **Preregistration** – Preregister your study + analysis plan
- **Informative file naming** - The rules don't matter. That you have rules matters.

2. Keep track of things

- **Version control** – Track your changes
- **Documentation** – Document everything done by hand

3. Contain bias

- **Reporting** – Report transparently + completely

4. Archive + share your materials

- **Where doesn't matter.** That you share matters.

How to learn more

- Organizing a project for reproducibility
  - Reproducible Science Curriculum by Jenny Bryan
  - https://github.com/reproducible-science-curriculum/
- Data management
  - Data Management from Software Carpentry by Orion Buske
  - http://software-carpentry.org/v4/data/mgmt.html
- Literate programming
  - Literate Statistical Programming by Roger Peng
  - https://www.youtube.com/watch?v=YcJb1HBc-1Q
- Version control
  - Version Control by Software Carpentry
  - http://software-carpentry.org/v4/vc/
- Sharing materials
  - Open Science Framework by Center for Open Science
  - https://osf.io/

Where to get help

reproducibility training	stats-consulting@cos.io
osf support	support@osf.io
work with COS	contact@cos.io

Q + A

- How might OSF fit into a workflow that uses USGS repositories for data publication (such as USGS ScienceBase, or NWIS)?
- How is OSF different from other workflow software such as Taverna, Kepler, etc.?
- How can OSF save me time? Generally takes large amounts of time to document.
- Can OSF document processing, analysis and results?
- What are some best practices for documenting scientific workflow for *new/exploratory methods* in data processing and analysis?